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LEAD INGESTION HAZARD IN HAND SOLDERING ENVIRONMENTS  
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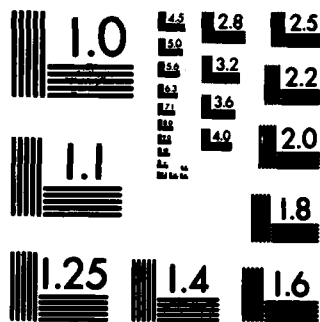
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# Lead Ingestion Hazard in Hand Soldering Environments

AD-A145 663

by  
Elisabeth R. Monsalve  
*Safety and Security Department*

MAY 1984

**NAVAL WEAPONS CENTER  
CHINA LAKE, CALIFORNIA 93555**



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### FOREWORD

Hand soldering is an essential operation in electronic component development at the Naval Weapons Center. Soldering is performed in many and varied settings at NWC by a variety of personnel, and many of the soldering operations are not isolated from other activities and workspaces, including offices. The potential hazard associated with lead soldering in these environments is not well-defined.

The study described in this report was undertaken to explore one of the potential health hazards associated with hand soldering—lead exposure—and to support practical recommendations to control the hazard. The study was conducted from September through December 1983, and was supported by NWC's Safety Program Office and Soldering Technology Branch.

Personnel whose assistance in this study is gratefully acknowledged are Jim Raby for his interest in the health of solderers, Linda Roush for statistical assistance, and Alice M. Parker for encouragement and material support.

This report was reviewed for technical accuracy by A. D. Wiruth, Head of the Safety Program Office.

The report is not in the usual NWC format and style, and was presented as a paper at the Eighth Annual Soldering Technology and Product Assurance Seminar held at NWC on 22 and 23 February 1984.

Approved by  
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24 May 1984

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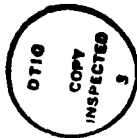
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(U) Hand soldering, an essential operation in electronic component development at the Naval Weapons Center, is performed in many settings by a variety of personnel at NWC. This report describes a study that explores one of the potential health hazards associated with hand soldering—lead exposure—and supports practical recommendations to control the hazard. The study was conducted from September through December 1983.

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## INTRODUCTION

Amid advancing soldering technology and the proliferation of automated techniques, hand soldering remains a mainstay in a number of electronics applications (Reference 1). Hand soldering with an iron, and pretreatment of components by pot tinning are very much in evidence in a research and development facility like the Naval Weapons Center, where many and varied one-of-a-kind electronic component prototypes are produced.

Soldering, more specifically hand soldering and pot tinning used in electronics applications, has not traditionally been considered a high lead hazard operation or occupation. Eminent toxicologist Elkins characterized the overall lead hazard in soldering operations as "minor" (References 2 and 3). As late as 1977, in a comprehensive monograph on lead, the World Health Organization (WHO) did not include soldering *per se* in its listing of lead hazardous industries/operations (Reference 4). Automobile radiator repair, which does involve a heavy form of soldering, was rated as highly hazardous. The Lead Industries Association (LIA) asserts in a soldering safety manual (Reference 5) that there is relatively little general hazard, or hazard from lead fume, in soldering operations because of the low temperatures involved (650-900°F). The manual cites extensive air sampling data confirming lead levels below the current Occupational Safety and Health Administration (OSHA) action level of 0.03 mg/m<sup>3</sup> (30 µg/m<sup>3</sup>). However, the potential hazard of lead ingestion was alluded to briefly in a statement regarding the importance of "good personal hygiene habits" and the prohibition of smoking, eating, and drinking in lead exposure areas. In assessing the lead hazard associated with the use of low melting point lead alloys (200-600°F) to construct radiotherapy shielding, no significant lead fume was detected. Handling procedures to minimize ingestion were recommended (Reference 6).

The National Institute of Occupational Safety and Health (NIOSH) does list "solderer" as an occupation in which lead exposure may occur; the type of soldering and nature of the potential exposure are not qualified (References 7 and 8). Yet in four separate health hazard evaluations of industrial hand soldering and pot tinning environments from 1974 to 1980, almost all airborne lead samples were below detection limits, blood-lead indices were well within normal range, and it was determined that no health hazard from lead appeared to exist (References 9 through 12). One of the studies does suggest a potential lead ingestion hazard in a recommendation regarding close attention to worker hygiene, including prohibition of eating or smoking in the workplace (Reference 9).

In 1978, OSHA promulgated a stringent revision of the Occupational Exposure to Lead Standard that governs over 120 operations involving the use of lead and includes hand soldering (References 13 and 14). In the contracted technical feasibility study (Reference 15) for the Standard, however, "electronics" was categorized as an industry in which lead exposures were almost exclusively below the then proposed 0.1 mg/m<sup>3</sup> (100 µg/m<sup>3</sup>) permissible exposure limit. Lead exposures were further described as very low.

Western Electric Company, in a biological study to support the exclusion of hand soldering operators from the OSHA Lead Standard (Reference 16), maintains that solderers' airborne lead exposures have been demonstrated to be "extremely low." Forty long-term hand solderers were found to have blood lead indices comparable to a control group of office workers with no known exposure to lead. In justifying the biological monitoring methodology of the study, environmental air measurements are dismissed as limited because lead exposure may also occur by means of skin absorption or ingestion.

Burgess (Reference 17) describes potential health hazards to soldering operators as "minimal," stating that flux may represent the most significant potential hazard. Temperatures routinely used are considered too low to generate significant fumes, although handling of dross dust may be a source of exposure to lead. Most interestingly, Burgess admits that his position should be reconsidered in light of the present  $0.50 \text{ mg/m}^3$  ( $50 \text{ }\mu\text{g/m}^3$ ) OSHA permissible exposure limit for lead.

Elaborating on Burgess' theme, the 1978 OSHA revised Lead Standard represents a substantial conservative evolution in scientific thought and increasing regulation in regard to the hazards of lead. The Standard revises the permissible exposure limit to lead in air downward threefold from  $0.15 \text{ mg/m}^3$  ( $150 \text{ }\mu\text{g/m}^3$ ) to  $0.05 \text{ mg/m}^3$  ( $50 \text{ }\mu\text{g/m}^3$ ) and mandates biological monitoring of lead workers and strict control of workplace exposures. Much of the research upon which the standard is based demonstrates subtle or subclinical toxic effects of lead in workers at relatively low levels previously considered to be "safe" (Reference 14). Although actual exposures to lead may not have increased and may actually be decreasing due to improved awareness and technology (References 3, 7, and 8), increasing knowledge of the toxicology of lead dictates a continuing reassessment of the hazard it presents. The potential hazard associated with even low-level exposures to lead may indeed have implications for solderers.

The toxic effects of inorganic lead in man have been known since ancient times and numerous toxicological investigations span over 150 years (Reference 3). Lead is a cumulative poison whose effects on the hematological, neurological, and renal systems are well documented. *Classic signs of frank poisoning in adults such as intestinal colic, anemia, brain dysfunction, convulsions, upper extremity weakness, wrist drop, and kidney failure are rarely seen in the United States today* (References 3, 7, and 8). Of more relevance to this investigation is a discussion of newer findings of more controversial subclinical effects of lead at low levels of exposure (References 18 through 25).

Subclinical effects of lead are physiologic changes undetectable except by increasingly sophisticated biological monitoring techniques. They appear much earlier than the signs and symptoms of overt disease. Many medical researchers feel that these changes are "critical effects," the precursors of disease, early manifestations on a continuum. Exposures that induce subclinical critical effects must be reduced to prevent occupational illness. Others, often industry representatives, argue that the clinical significance of these early changes is dubious; there is not enough evidence to demonstrate that these changes represent or lead to a material impairment of health (References 14 and 26).

To place subclinical toxicological findings in perspective, an attempt must be made to characterize "low" levels of exposure. The measurement of lead exposure and human response to exposure are, in themselves, a complex and controversial issue beyond the scope of this discussion. The advantages, disadvantages, and predictive relationships between biological



monitoring indices and environmental sampling data have been weighed extensively (References 14 and 27). It is noteworthy that OSHA, in Solomon fashion, has required both environmental and biological monitoring in the Lead Standard. The toxic effects of lead exposure are generally discussed in the context of blood lead levels, although this is only a measure of recent or continuous exposure. Blood lead may be misleading because of the cumulative nature of this poison and the variability of human response to it (References 16, 22, 27, and 28). Other biological indices, such as red blood cell protoporphyrins measured as zinc protoporphyrin (ZPP), may be more accurate and useful in assessing levels of toxicity because they estimate total body burden and *response* to exposure. A recent estimate of mean blood-lead level in adults in the United States is 13 to 14  $\mu\text{g}/\text{dl}$  (deciliter) (Reference 29). Traditionally, lead related disease was not thought to occur at blood levels below 80  $\mu\text{g}/\text{dl}$  (References 14, 18, and 30). The Lead Standard requires that blood-lead levels be kept below 50  $\mu\text{g}/\text{dl}$ . WHO recommends an upper limit of 40  $\mu\text{g}/\text{dl}$  for adult workers (Reference 31). Substantial recent research demonstrates overt clinical and subclinical toxic effects at blood levels as low as 40 to 60  $\mu\text{g}/\text{dl}$  (References 18 through 25, 32, and 33).

It has long been known that lead has an effect on the blood-forming system at relatively low levels; this information is the basis for laboratory diagnosis of lead absorption and poisoning. In the absence of the anemia of frank poisoning, these findings are thought by some to be reversible subclinical effects of unknown significance. Others argue that these alterations reflect the "general toxicity of lead in the entire body" (Reference 14). Of perhaps more dramatic concern are reports of potentially nonreversible subclinical changes in the human nervous system and human reproduction.

There are an increasing number of disturbing reports describing nervous system changes in asymptomatic workers at "safe" levels of exposure as low as 50  $\mu\text{g}/\text{dl}$ . Decreased nerve conduction velocities have been shown to be an early indicator of lead induced neurological damage (References 18 and 20). Subsequent research strongly suggests that changes in neurobehavioral patterns in asymptomatic lead workers may be an even more sensitive indicator of toxicity at low levels of exposure. Deficits in visual reaction time and auditory function have been reported in workers with a mean blood lead of 46  $\mu\text{g}/\text{dl}$  (Reference 20). Visual intelligence and visual motor tasks were found to be significantly affected in a group whose blood lead levels were  $32 \pm 11$   $\mu\text{g}/\text{dl}$  and had never exceeded 70  $\mu\text{g}/\text{dl}$  (Reference 21). Based on findings of decreased psychological performance test scores at low levels of lead absorption indicated by low ZPP, it has been concluded that even non-occupationally exposed groups, with environmental exposures to lead in air, food, and water, may be at risk for central nervous system dysfunction (Reference 23). A very recent work in progress describes deteriorating neurobehavioral function in verbal concept formation, visual/motor performance, memory, and mood with increasing lead intake in workers with blood-lead levels as low as 40 to 60  $\mu\text{g}/\text{dl}$ . The report concludes that central nervous system abnormalities occur well before peripheral nervous system disruption at lower blood levels ( $<60$   $\mu\text{g}/\text{dl}$ ) and shorter periods of exposure ( $<6$  months) (Reference 25).

Lead exposures at low or safe levels are also being reassessed in regard to effects on reproduction and the unborn. OSHA concluded that lead severely affects the reproductive capability of males and females; all workers planning pregnancies should keep their blood lead levels below 30  $\mu\text{g}/\text{dl}$ . Blood lead levels apparently as low as 30 to 40  $\mu\text{g}/\text{dl}$  may result in decreased fertility in men (Reference 19). Fetal exposure is the critical issue in assessing occupational lead exposures in women because lead readily crosses the placental barrier, and lead in the umbilical cord blood correlates well with that in the blood of the mother. Given the

Center for Disease Control lead poisoning limit of 30  $\mu\text{g}/\text{dl}$  for children, this same limit should apply to women who are or are likely to become pregnant. Since the blood/brain barrier in the newborn is relatively immature, and central nervous system growth is very dramatic during fetal life, there is at least as much, if not more, concern for the fetus as the child (References 34 and 35). This upper limit for women of 30  $\mu\text{g}/\text{dl}$  is also recommended by the WHO (Reference 31).

The question of a health hazard from lead in hand soldering and pot tinning environments appears to be moot. The literature suggests that there is little, if any, exposure to airborne lead because of the low temperatures involved (References 1, 5, 6, 36, and 37). The possibility of lead ingestion is briefly mentioned (References 1, 5, 6, 9, 16, and 37), but the potential hazard has neither been explored nor quantified. One factor contributing to this dearth of attention may be methodological difficulties. More likely is the notion that the necessity to avoid ingestion is axiomatic; the means are obvious and easy.

In the production soldering environment, the rationale for good hygiene may be accepted by employees without quantitative justification. The prohibition of eating, drinking, smoking, and cosmetics applications and the use of gloves and handwashing are compatible with quality control; therefore, they are further reinforced. Hygiene regulations may be relatively easy to enforce despite lapses caused by subtle, inadvertent human habits. "Clean" areas for eating, drinking, and smoking are generally designated and accepted.

In the less regimented and structured milieu of a research and development facility, or even of the home hobbyist, soldering and pot tinning are performed in many types of settings. These areas may be used for other functions throughout the workday and may be the employee's only workspace. In these circumstances, hygiene regulations may seem unduly restrictive and problematic. A rationale supported by data may be very desirable.

In light of research suggesting significant toxicity, especially neurological and reproductive, at low lead levels previously considered to be safe, it was felt that a study to explore a potential lead ingestion health hazard in soldering environments was needed. Study objectives were twofold:

1. To confirm the absence of airborne lead in soldering and pot tinning environments at levels significant to constitute an inhalation hazard or source of surface contamination.
2. To determine the presence or absence of removable lead contamination on accessible surfaces in amounts significant to constitute an opportunity for a lead ingestion hazard.

## EXPERIMENTAL DESIGN

### SAMPLE SELECTION

Rough estimates suggest that there are 500 to 600 separate electronics-type soldering and tinning environments, i.e., work areas for one operator, scattered throughout most operations at the Naval Weapons Center. Areas and operators were selected on the basis of interest, cooperation, and availability and were felt to represent a range of overall typical activities. A

majority of the samples were collected at soldering class laboratory sessions held at the Center on an ongoing basis. The soldering laboratory is a somewhat idealized setting in which hygiene and quality control measures are strictly observed. It was felt that potential environmental contamination itself, however, would still be of interest and not differ significantly from less ideal settings. All soldering operations employed a temperature-controlled hand soldering iron (e.g., Thermo-Trac, Weller) set at approximately 700°F. Eutectic solder (63% tin, 37% lead) was used with mildly activated rosin (RMA) flux.

Wipe samples for the control group were taken from working surfaces in the general vicinity of the soldering area, i.e., the same large room or building, when it was determined that soldering had not and was not being performed on or near that surface. Several control samples were taken from work surfaces in various rooms of a building where soldering was never performed.

Air samples were collected during actual soldering operations. Wipe samples were taken at times when soldering may or may not have been in progress. No attempt was made to correlate air and wipe sampling. Each surface wipe sample characterizes a separate soldering environment. The air samples separately measure 13 of these environments.

#### AIR SAMPLING

All air samples were collected on 37 mm 0.8  $\mu$ m millipore AA mixed cellulose ester membrane filters connected to a Bendix BDX 44 Super Sampler pump (Figure 1). The sampling pump was set for an airflow of 2.0 liters per minute and was calibrated before and after sampling to assure volume. All sample cassettes but one were positioned approximately 6 to 16 inches above the soldering work. It was felt that source zone samples would be less intrusive than samples placed on the operator. In addition, source zone samples should represent the "worst condition" because of their proximity to the fume generation point and their continuous exposure, even when the operator temporarily left the area. The one exception is a personal



FIGURE 1. Air Sampling Train. Cassette 6 to 16 inches above soldering work (A). Pump unit (B).

sample, collected at operator request with the sampling cassette attached to the operator's collar (Table 1).

TABLE 1. Air Sampling Results.

Sample no.	Pb $\mu\text{g}/\text{m}^3$	Sample no.	Pb $\mu\text{g}/\text{m}^3$
1	none detected	8	none detected
2	none detected*	9	none detected
3	none detected	10	none detected
4	none detected	11	none detected
5	none detected	12	2 $\mu\text{g}$
6	none detected	13	2 $\mu\text{g}$ **
7	none detected		

\*Personal sample.

\*\*Pot tinning sample.

Sampling time ranged from 120 to 147 minutes and sample volume ranged from 216 to 300 liters. Potential lead fume generation was not expected to be and was not constant during the period sampled since the soldering performed was transient and very sporadic. Although this is not inconsistent with the nature of hand soldering in electronics applications, it might be expected that more actual soldering might have occurred during the sampling period in a production environment. Whether or not potential constant or average fume levels could increase is debatable, but unlikely, because of the temperatures involved. The time period sampled represented the minimum required by the analytical method and included or exceeded the solderer's actual soldering exposure for that day. Residual fume in the air after soldering had ceased might be expected to be included in a number of samples. In those cases where the operator's soldering activity for the day exceeded the period sampled, it was not expected that potential exposure during the unsampled periods would differ significantly. The tinning pot sampled is an exception, in that any fume generation would be expected to be relatively constant.

Mechanical ventilation was not employed in any soldering or pot tinning environment sampled. Natural ventilation often included airflow from air conditioning systems and was felt to be good.

All samples were analyzed by atomic absorption spectrophotometry with a limit of detection of 1  $\mu\text{g}$ .

#### WIPE SAMPLING

Sampling for surface contamination was performed using essentially the OSHA wipe sampling technique (Reference 38). It consists of wiping a 100-cm<sup>2</sup> surface with a 7-cm Whatman 42 filter paper moistened with water. Care was taken to minimize artifactual lead contamination and sampling error by using hospital supply sterile distilled water. The background lead in the filter paper as specified by the manufacturer was 0.2  $\mu\text{g}/\text{g}$ , an amount

considered to be insignificant for the study purpose. The sampler wore a fresh disposable vinyl glove for each sample. Standardization of the size of the surface area wiped was attempted using a vinyl template, cleaned prior to each use (Figure 2).

Wipe samples for the experimental group were taken from an area of the work table or bench directly accessible to the solderer. Types of surfaces included bare wood, Formica, Masonite, and soft vinyl mats. Control group wipes came from desk or table surfaces of "woodgrain" vinyl, Formica, or painted metal.

Samples were also taken from solderers' hands. Only in the classroom were vinyl disposable gloves worn and samples were taken from the gloved hand in these instances. Bare skin or gloved, samples were obtained by wiping the lateral and palmar surfaces of each finger from palm to tips and the palm itself. Each sample includes both the right and left hand, and the sampler attempted to perform the wiping in the same fashion for each sample.

Field blanks were submitted with each sample batch. All samples were analyzed by atomic absorption spectrophotometry with a limit of detection of 1  $\mu\text{g}$ .

There is little guidance or precedence for the assessment of surface lead contamination by wipe sampling or any other methodology. Attempts to use wipe sampling in the assessment of the health hazard presented by beryllium surface contamination and resuspension (Reference 39) and radiation surface contamination (Reference 40) resulted in the conclusion that the method is strictly qualitative, i.e., may determine the presence or absence of contamination. OSHA policy (Reference 38) tends to support this conclusion by stating that wipe sampling is used to document the presence of a hazardous substance and may not support a citation, but is rather complementary to all other available evidence about a hazard and requires case-by-case professional judgement. In addition, there are no published OSHA standards or guidelines by which to evaluate results.

Wipe sampling has been used "semiquantitatively" to evaluate household lead surface dust as a source of lead exposure in children (References 40 and 41). In the absence of standards, the findings were treated somewhat quantitatively by comparing them with findings in control samples and "before and after" samples and arbitrarily labeling the samples as "high" and

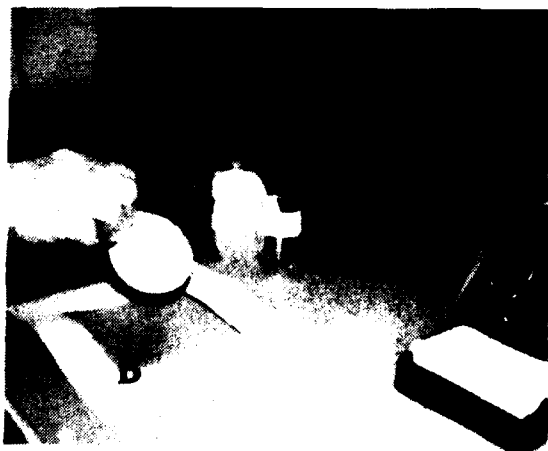


FIGURE 2. Wipe Sampling Equipment. Whatman 42 filter moistened with water (A). 100-cm<sup>2</sup> surface area outlined by vinyl template (B).

"low." Both of these studies, as well as this investigation, test hypotheses with a common element—that a significant quantity of removable lead surface contamination is present to provide an *opportunity* for a lead ingestion hazard. The "opportunity" hypothesis does not require the testing precision necessary to prove actual ingestion of specific amounts of lead to correlate lead exposure with absorption and effect, or to compare results with standards. Therefore, for the purposes of this study, wipe sampling was selected as a useful, semiquantitative, exploratory technique.

In using wipe sampling to assess a possible lead ingestion health hazard, some speculation about the nature of removable lead surface contamination is warranted. Since it has been theorized that temperatures used in hand soldering are too low to generate significant lead fume, it follows that the major vehicle for lead surface contamination is likely to be direct physical transfer from solder and dross to various surfaces. The contamination is likely to consist of lead oxides and oxycarbonates readily removed during contact with solder (References 1, 37, 42, and 43) and dust from dross (Reference 17). Lead in these forms, if ingested in sufficient quantity, could be expected to produce toxic effects (References 1, 37, 44, and 45).

## RESULTS AND DISCUSSION

In 11 of 13 air samples (Table 1) collected during separate soldering operations, lead fume was undetectable. Fume levels in the remaining two samples were considered to be insignificant against an OSHA permissible exposure limit of  $50 \mu\text{g}/\text{m}^3$ . The data substantially support the first study objective, to confirm that lead fume is not generated during soldering operations in amounts significant to constitute an inhalation hazard or source of surface contamination.

Given the expected range of sample values and the estimated population, the number of experimental and control surface wipe samples (Table 2) were considered to be adequate. The

TABLE 2. Wipe Sampling Results.

Soldering surfaces				Control		Solderers's hands	
Sample no.	Pb $\mu\text{g}/100 \text{ cm}^2$	Sample no.	Pb $\mu\text{g}/100 \text{ cm}^2$	Sample no.	Pb $\mu\text{g}/100 \text{ cm}^2$	Sample no.	Pb $\mu\text{g}/100 \text{ cm}^2$
1	0	11	13	1	none detected	1	3
2	1	12	14	2	none detected	2	3
3	2	13	17	3	none detected	3	3
4	3	14	27	4	1	4	5
5	4	15	45	5	1	5	6
6	5	16	47	6	1	6	14
7	7	17	70	7	1	7	15
8	8	18	70	8	3	8	15
9	9	19	80	9	3	9	16
10	13	20	92	10	3	10	20
						11	32

experimental soldering surface results were pooled and divided into 10- $\mu$ g incremental bands. The control results were treated similarly (Figure 3). It can be seen that all of the soldering wipe results are under 100  $\mu$ g and 80% are under 51  $\mu$ g. All of the control values are less than 11  $\mu$ g.

There is a statistically significant difference between the experimental and control groups when the presence or absence of detectable lead is constructed as a binomial experiment. The null hypothesis that there is no difference between the lead surface contamination in soldering and nonsoldering environments can be rejected.

Wipe sample data from solderers' hands (Table 2) were not included in data analysis. The data are presented to highlight the lead ingestion opportunity presented by contamination on surfaces particularly accessible to the mouth.

The data do indicate measurable removable lead surface contamination in support of the second study objective of demonstrating opportunity for ingestion. In evaluating "opportunity," a number of unknowns and potentially confounding variables are encountered. The nature and quantity of the solderers' actual contact with contaminated surfaces and subsequent combinations of object hand-to-mouth activity were not assessed. This activity could be highly variable and unpredictable among individuals. In addition, the equivalency of wipe sampling in picking up lead contamination to real-world hand-object-mouth interfaces is unknown. Quantitation is further obscured in a number of ways. Intermediate objects capable of conveying lead (e.g., food, pen) could not be assessed. Surfaces and hands are treated as separate contributions. It was not possible to differentiate additive versus substitutive contributions to overall intake carried to the mouth. That is, the possibility exists that some surface contamination, by virtue of being removed from a surface, could become less available for ingestion and should be subtracted from overall potential intake possibilities!

In order to deal with this morass of variables, the assumption is made that all lead found in any single wipe sample was conceivably ingested. This assumption is felt to be a conservative overestimate appropriate to evaluating a health hazard.

Even if the amount of ingestible lead could be accurately known, assessing the data in regard to a health hazard is still very problematic. Although models (References 14 and 46) have been proposed, there is still no consensus regarding a predictive relationship between exposure to lead in air or by ingestion, and blood-lead levels. In addition, as previously discussed, blood-lead levels are controversial as an index of exposure versus actual toxic effect or response to exposure.

WHO (Reference 47) addressed a number of these variables in establishing a provisional maximal or tolerable overall weekly lead intake for an adult. It is believed that this concept of total lead intake provides the most useful and valid framework for interpretation of study findings in regard to a potential health hazard. The WHO recommended ceiling of 3 mg (3000  $\mu$ g) per week takes into account the cumulative nature of lead poisoning. It presupposes that lead inhaled from the atmosphere will reduce the amount tolerable in food and water. Although in non-industrially exposed populations, lead in air contributes a much less significant fraction to the total than does food and water (200 to 300  $\mu$ g/day). In highly urbanized polluted areas, intake of lead by inhalation may contribute as much as 100  $\mu$ g/day.

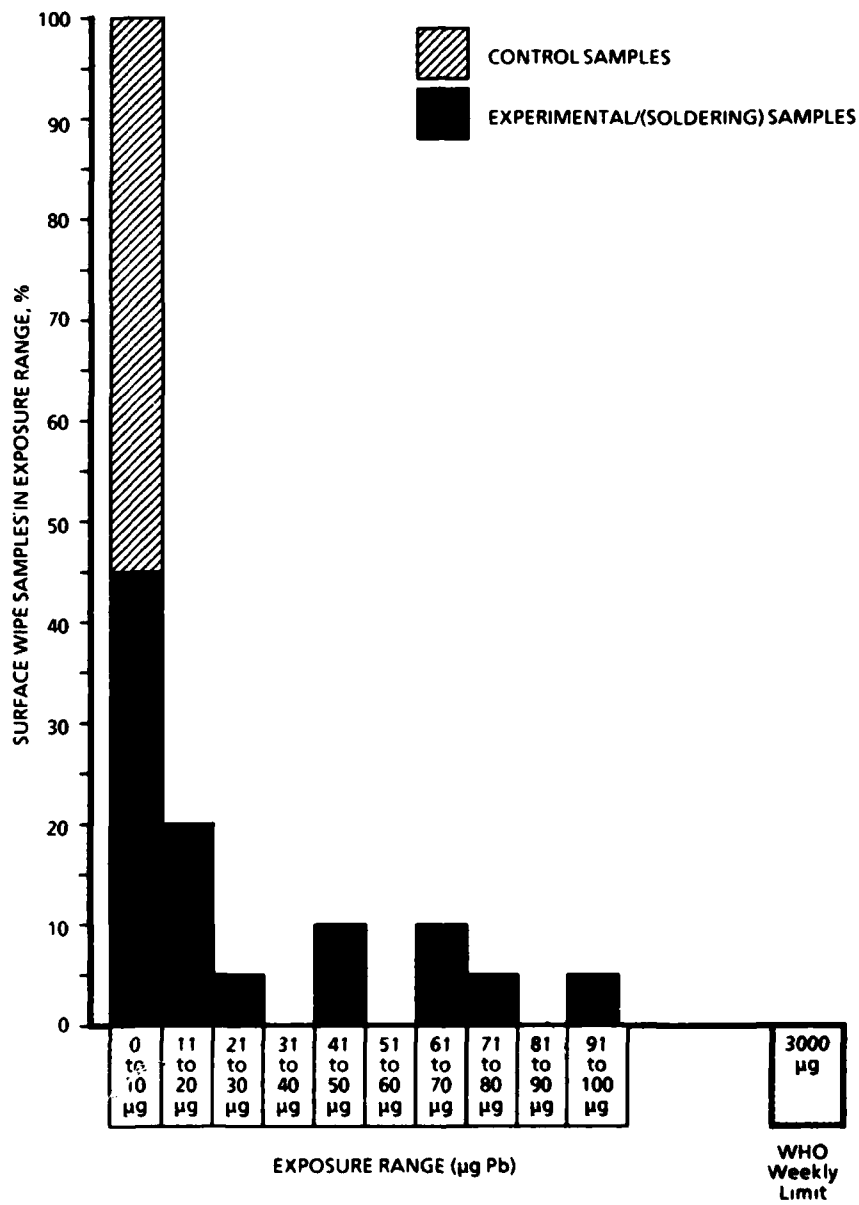


FIGURE 3. Percent of Surface Wipe Samples in Incremental Exposure Ranges.



TABLE 3. Calculation of Maximum Acceptable Lead Intake According to WHO Recommended Limit.

Source of Pb contribution	Total intake ( $\mu$ g)	
	Daily	Weekly
Food and water .....	200-300	1400-2100
Community air .....	100	700
	300-400	2100-2800
WHO recommended limit (5-day work week) .....	440-480	3000
Allowable contributions from all other sources including soldering (5-day work week) .....	40-180	200-900

It can be seen from simple calculations (Table 3), that after the "normal" weekly intake from air, food, and water is totaled, there exists a leeway of 200 to 900  $\mu$ g. Thus, 200 to 900  $\mu$ g of lead per week could be contributed from soldering before tolerable values were exceeded. Assuming that the solderer ingests a full wipe sample value (Table 2) on each of 5 days per week, it can be shown that acceptable intake levels could be marginally exceeded. Using a mathematical model (Reference 46), ingestion of 20 to 30  $\mu$ g of lead per day (mean wipe sample value—Table 2) added to "normal" daily intake of 200 to 400  $\mu$ g, could result in a blood lead level of 23 to 45  $\mu$ g/dl. As previously stated, subclinical toxic effects of lead have been demonstrated at blood lead levels as low as 40 to 60  $\mu$ g/dl, and 30  $\mu$ g/dl is the recommended limit for men and women of childbearing age. It should be emphasized that these calculations assume no other industrial lead exposures. They do not account for the presumably significant amount of lead that could be ingested during the practice, observed during the study, of holding solder wire in the mouth, using the mouth as a "third hand." The totals do not include the not uncommon off work lead exposures such as hobby soldering, spray painting, shot pouring, use of lead pigments in painting and ceramics, indoor target practice, etc. In the Naval Weapons Center rural desert environment, the figures probably overstate lead intake from community air pollution.

Given a magnitude in micrograms and relatively narrow tolerances, this delicate balance between lead absorption and poisoning could easily be upset by any exposures other than the "usual" in food, water, and air. It should also be noted that the WHO recommended limit was made prior to most of the research on subclinical toxicity of lead at low levels of exposure and could be conceivably reduced even further in the future.

## CONCLUSIONS

1. No significant inhalation hazard from lead fume exists in soldering and pot tinning environments. In addition, lead fume is not a significant source of surface contamination. The practical implications are that mechanical exhaust ventilation and physical isolation of soldering areas are not essential to prevent a lead hazard. (Irritating and/or toxic decomposition products of flux may require ventilation, however.) Lead contamination may be spread to adjacent areas by accumulation of gross dust and/or solderers' contaminated hands.

2. A low-order lead ingestion hazard exists in nonproduction soldering environments. This hazard may easily be substantially increased by such common practices as placing solder wire in the mouth, using the mouth as a "third hand." The hazard may also be increased by lead exposures outside of soldering, which may not be uncommon.

3. Reasonable hygiene measures in areas where soldering is performed are justified. Handwashing prior to eating, drinking, smoking, and cosmetics applications should be the cornerstone. Other worthwhile measures include the avoidance of food or cigarette placement on bare working surfaces, and routine wet cleanup of working surfaces after soldering.

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